ADF

Saskatchewan Agriculture
Development Fund

Final Report

R-87-02-0276

Development of Conveying Equipment Guidelines for Optimum Pulse Crop Quality

Funded by
The Agriculture Development Fund
March 31, 1989

Keeping the agriculture and food industries competitive through Research, Development and Demonstration.

93-02729/

Final Report

R-87-02-0276

Development of Conveying Equipment Guidelines for Optimum Pulse Crop Quality

Funded by
The Agriculture Development Fund
March 31, 1989

Prepared by: Prairie Agriculture Machinery Institute

The views expressed in this report are those of the author(s). The Agriculture Development Fund (ADF) does not accept responsibility or liability for any conclusions or recommendations in the report, and cannot guarantee the accuracy of its data or observations.

ADF Project No. R-87-02-0276
PAMI Project No.: RH0288
March 31, 1989

FINAL REPORT

DEVELOPMENT OF

CONVEYING EQUIPMENT GUIDELINES

FOR OPTIMUM PULSE CROP QUALITY

R-87-02-0276

Prepared for:

Agriculture Development Fund
Saskatchewan Agriculture
Walter Scott Building
3085 Albert Street
Regina, Saskatchewan
S4S 0V1

Saskatchewan Wheat Pool
2625 Victoria Avenue
Regina, Saskatchewan
S4T 7T9

Saskatchewan Pulse Crop
Development Board
Box 516
Regina, Saskatchewan
S4P 3A2

Manitoba Pool Elevators
Box 9880
Winnipeg, Manitoba
R3C 3K7

Prepared by:

Prairie Agricultural Machinery Institute
P. O. Box 1150
Humboldt, Saskatchewan
S0K 2A0
(306) 682-5033

Acknowledgments

Funding of this research project has been provided by Saskatchewan Agriculture (through the Agriculture Development Fund), the Saskatchewan Pulse Crop Development Board, and the Manitoba and Saskatchewan Wheat Pools.

The following machinery firms also supported this project by supplying test machines.

Brandt Industries Ltd.

Farm King Allied Inc.

Speed King Industries Inc./Ramboc Enterprises Ltd.

Sudenga Industries Inc./Gaber Distributors Ltd.

Westfield Industries Ltd.

PAMI gratefully acknowledges the contributions made by the funding agencies and by the machinery firms. Without such support, this research project would not have been possible.

TABLE OF CONTENTS

	PAGE
ABSTRACT	1
TECHNICAL REPORT	2
1. INTRODUCTION	2
2. OBJECTIVES	3
3. GENERAL DESCRIPTION OF TEST MACHINES	3
4. SCOPE OF TESTS	8
4.1 Damage Tests	8
4.2 Capacity Tests	9
4.3 Power Tests	9
4.4 Economic Analysis	10
5. RESULTS AND DISCUSSION	15
5.1 Damage	15
5.2 Capacity	20
5.3 Specific Capacity	23
5.4 Economic Analysis	27
5.5 Other Considerations	30
6. CONCLUSIONS	31
SUMMARY REPORT	33
PROPOSED PUBLICATIONS	35
EXPENDITURES	36
PERSONNEL	37
EQUIPMENT PURCHASED	38
APPENDICES	
APPENDIX I Terminology	39
APPENDIX II References	40
APPENDIX III Damage Data Tables	41
APPENDIX IV Capacity Data Graphs	43
APPENDIX V Power Data Graphs	46
APPENDIX VI Economic Analysis Calculation Tables	50

ABSTRACT

Under funding by Saskatchewan Agriculture (through the Agriculture Development Fund), the Saskatchewan Pulse Crop Development Board, and the Saskatchewan and Manitoba Wheat Pools, tests were conducted on four conveyors commonly used to handle pulse crops. Two screw conveyors were tested, one with steel flighting and the other with bristle flighting. A paddle conveyor and a belt conveyor were also tested. The conveyors were tested to compare crop damage, capacity and specific capacity (efficiency of power usage) in peas and lentils at two moisture contents.

There were considerable differences in performance amongst the conveyors in the various crop conditions. An economic analysis showed that pulse crop producers could save considerable money by choosing the right equipment for their situation.

TECHNICAL REPORT

1. INTRODUCTION

There are currently about 3800 pulse crop producers in Saskatchewan. In 1986 they produced approximately $81 million worth of these crops and current trends indicate the industry is growing. Pulse crops are more susceptible to damage than cereals and other grains and the associated costs are much greater than cereals due to a higher market price.

On-farm cleaning of pulse crops is an option but is still quite expensive and very time consuming. Furthermore, cleaning is only effective if subsequent handling equipment does not re-introduce excessive damage.

Recently a number of conveyors designed specifically to reduce crop damage have been introduced onto the market. The manufacturers of these conveyors have endeavored to produce a conveyor with low crop damage, while maintaining high capacity and low power requirements.

This study was undertaken to provide basic performance information on four types of conveyors. The information will be useful to pulse crop producers and processors and to manufacturers of pulse crop conveying equipment.

2. OBJECTIVES

The objectives of this project were to:

1. Assess pulse crop damage in four unique conveyors commonly available in the prairies.
2. Measure capacity and power requirements of these four conveyors in pulse crops.
3. Develop an economic comparison of the conveyors and suggest operating guidelines in pulse crops.
4. Provide useful information on the conveyor performance to pulse crop producers, processors and manufacturers of pulse crop conveying equipment and to extension personnel of the sponsoring agencies.

3. GENERAL DESCRIPTION OF TEST MACHINES

Four conveyors commonly used for handling peas and lentils in Saskatchewan were compared in this study, as follows:

- Conventional screw conveyor with steel flighting
- Conventional screw conveyor with bristle flighting
- Paddle conveyor
- Belt conveyor

The screw conveyor with steel flighting used in the study was 8 in (200 mm) in diameter, 40 ft (12.2 m) long with double flighting at the inlet (FIGURE 1). The remainder of the flighting was single pitch. This conveyor comes in a variety of diameters and lengths. It is the most common type of grain conveyor found in the prairies and there are at least eight manufacturers of these in the prairie provinces.

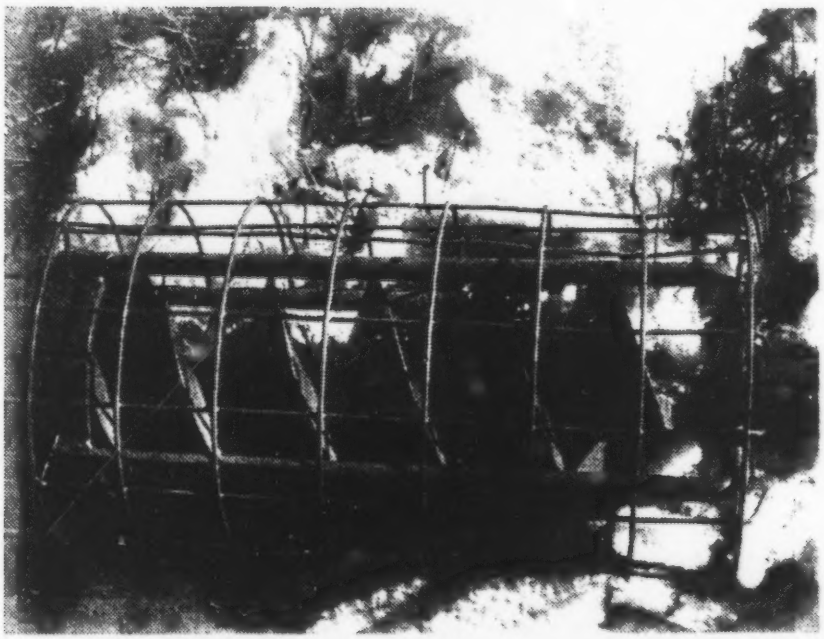


FIGURE 1. Steel Flighting Screw Conveyor Inlet.

The bristle flighting consisted of a 6 in (150 mm) steel flighting with 1 in (25 mm) nylon bristles fastened radially around the outside edge. This flighting then fit into a regular screw conveyor tube to produce a test machine 8 in (200 mm) in diameter and 41 ft (12.5 m) in length. The bristle flighting was single pitch the entire length of the auger tube (FIGURE 2). It was developed for use in fragile crops and is available in a variety of diameters and lengths. PAMI was unable to locate manufacturers of bristle flighting in the prairie provinces, but some American manufacturers do have local distributors.

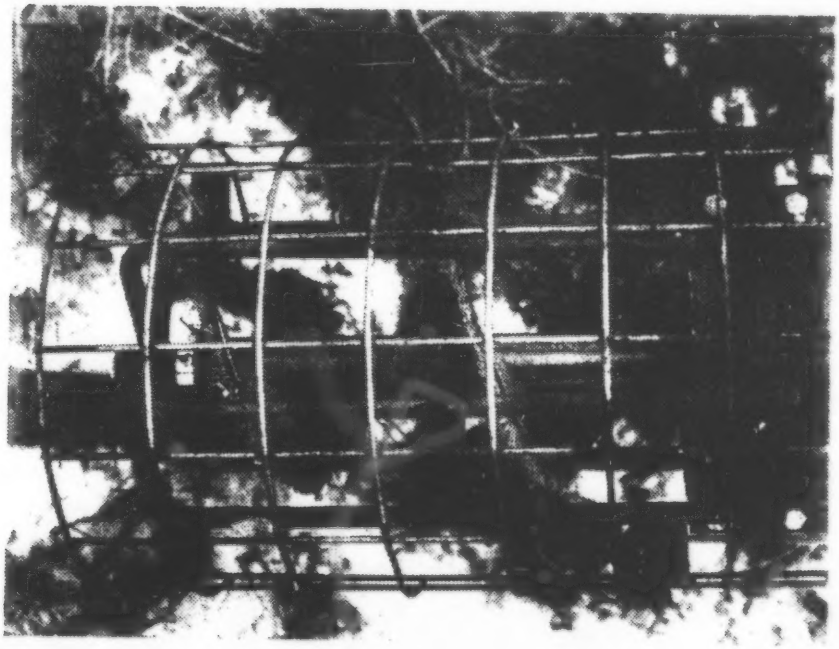


FIGURE 2. Bristle Flighting Screw Conveyor.

The paddle conveyor used 8 in (200 mm) wide by 4 in (100 mm) high rubber paddles spaced 6 in (150 mm) apart (FIGURE 3) and fastened to a continuous conveyor chain to convey grain through a square tube. A prototype paddle conveyor 60 ft (18.3 m) in length was used in the study since a 40 ft (12.2 m) paddle conveyor was unobtainable. Only one prairie manufacturer of paddle conveyors was located and no other distributors or manufacturers are believed to exist.

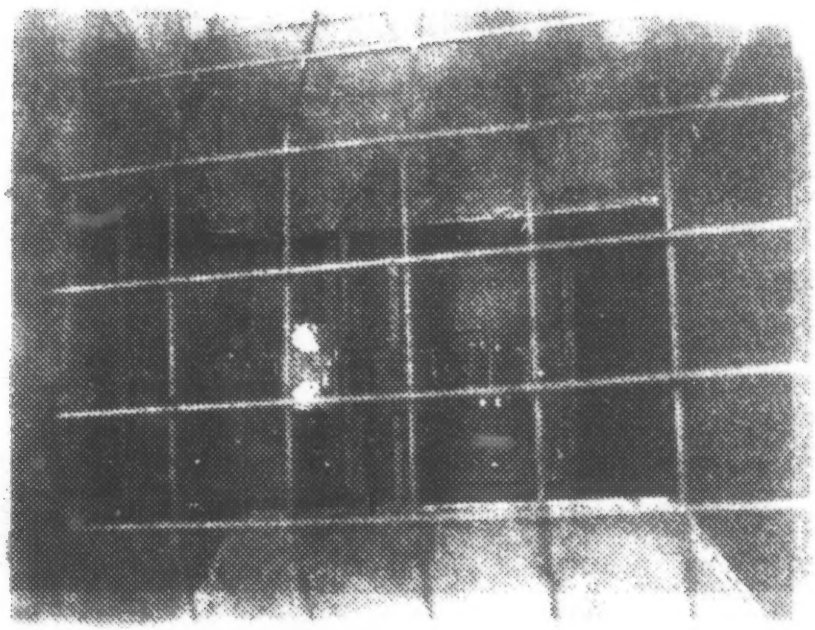


FIGURE 3. Paddle Conveyor Inlet.

The belt conveyor used a 12 in (300 mm) wide textured continuous belt (FIGURE 4) running inside a 10 in (250 mm) diameter, 50 ft (15.2 m) long tube. It was developed for use in fertilizer and fragile crops and is available in a variety of lengths. It is the conveyor of choice by most pulse crop processors to keep seed damage to a minimum. A few small manufacturers of belt conveyors are located in the prairies and at least one large American manufacturer has a local distributor.

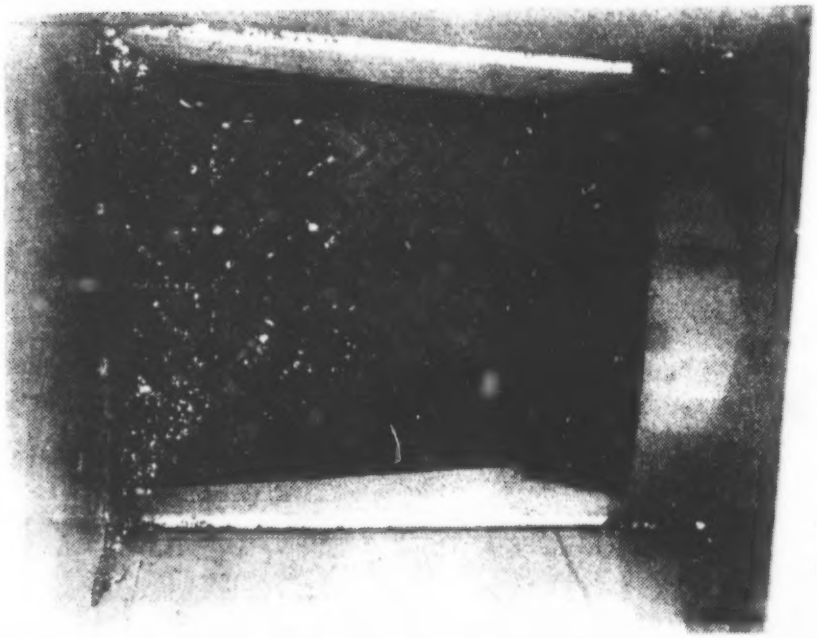


FIGURE 4. Belt Conveyor Inlet.

4. SCOPE OF TESTS

The four conveyors in this study were compared for crop damage, capacity and specific capacity (efficiency of power usage) in three crops. The crops used were 12.8% moisture content Laird Lentils, 15.4% moisture content Laird Lentils and 13.0% moisture content Century Peas. It was intended to include Century Peas at 16.0% moisture content in the study as well, but the dry harvest conditions in 1988 made peas of this moisture content unobtainable.

4.1 DAMAGE TESTS

The damage tests were performed using clean, relatively undamaged grain. All test machines were operated at 20^{o} and 30^{o} angles of elevation in the three crops. The machines were flood fed and were operated at or near their maximum capacities for all damage tests. As well, the machines were run at a low operating speed in the 15.4% moisture content lentils.

Samples were taken at the inlet and discharge spout of each conveyor while they were operating. These samples were analyzed by hand to determine the percent seed damage at each source. The damage at the inlet was subtracted from the damage at the discharge spout to give overall damage for one pass through the conveyor.

4.2 CAPACITY TESTS

The same crops and moisture contents as used in the damage tests were used in the capacity tests. Each conveyor was operated at 20° and 30° angles of elevation and the inlets were flood fed at all times. All conveyors were PTO driven with a 30 hp (23 kw) tractor and were operated over a complete range of operating speeds to develop a capacity curve.

The crops were conveyed into a wagon equipped with load cells for a certain period of time. The load cells measured the weight of material in the wagon at the beginning and end of each test. The weights were subtracted and this net weight was divided by the test time to give capacity.

4.3 POWER TESTS

At the same time as the capacity tests were conducted, power tests were also performed. Sensors were mounted to measure torque and speed in the PTO shaft as material was being conveyed through each test machine. The torque and speed data were used to determine the power input.

Similar to the capacity tests, the power requirements were measured over a complete range of operating speeds to develop a power input curve. The power data was used together with capacity data to calculate specific capacity.

4.4 ECONOMIC ANALYSIS

An economic analysis of the conveyors was performed by computing the total cost of each conveyor type. Total cost was made up of the following:

- reduction in product value from damage
- cost of power to operate conveyor
- fixed costs of conveyor
- repair cost to maintain conveyor
- labour cost to operate conveyor

Equations were developed for each of these component costs. Assumptions were also made to standardize other factors that might vary from farm to farm. These assumptions allowed the analysis to focus on the main items under study.

All of the equations account for the fact that grain is handled twice on most farms. The first handling is at harvest when it is conveyed from the truck into a storage bin. The second handling occurs when grain is conveyed from the bin into a truck for sale.

Product Value Reduction From Damage: Lentils and peas are treated differently by commercial pricing policies regarding value reduction due to physical damage. Lentils are classified into distinct grades according to the amount of physical damage. Each grade covers a range of damage values but each grade has a fixed price. Other types of damage are present in lentils which add to physical damage. Even small amounts of physical damage, when combined with other damage, could push the product's quality down to the next

grade. It was therefore decided to develop an equation which would account for product value reduction in terms of incremental changes in physical damage.

When damage occurs to pea seeds within a batch, the value of those seeds only is reduced, the entire batch is not down-graded. An equation for incremental damage cost may therefore be used for computing costs of pea damage also.

$$\text{Grain Damage Cost} = PV \times AP \times \frac{(2-DR)\ DR}{100}$$

Where: PV = Reduction in Product Value ($/lb)

AP = Annual Production (lb/yr)

DR = Damage Rate (%)

This equation yields cost of grain damage in dollars per year. The equation accounts for the fact that a seed can only be damaged once. The seeds damaged on first pass through the conveyor are not included in the amount used to calculate damage in the second pass.

From discussions with processors, it was determined that although lentil pieces change they always tend to lose value at a rate of about $0.01/lb ($0.02/kg) for every percentage point of damaged seed. This rate has been used in the equation but had to be multiplied by 100 to account for the units in the equation relating to percentages.

The opinion of pea processors was that over the recent past each percentage point of damage caused reduction in value of about $0.0208/lb ($0.046/kg). This has been used in the computations.

Cost of Power: For standardized comparison, it was assumed that all conveyors would be PTO driven with a 45 hp (34 kw) tractor. Information from page 8 of the Farm Machinery Custom and Rental Guide (1988) was used to calculate a cost for this tractor size of $0.24/hp-h ($0.32/kW-h).

The specific capacity (lb/hp-h) of each conveyor was determined by combining the power and capacity test data. Power costs were computed using the following equation and have units of $/yr.

$$\text{Power Costs} = [TC/(C/P)] \times AP \times 2$$

Where TC = Tractor Cost ($/hp-h)

C = Conveyor Capacity (lb/h)

P = Conveyor Power Requirements (hp)

AP = Annual Production (lb/yr)

Fixed Conveyor Costs: Fixed costs were made up of depreciation, investment, insurance and housing costs. Each of these component costs were calculated using the formulae shown on page 29 of the Custom and Rental Guide. Information from page 30 of the Guide was used to develop a formula for conveyor life time, based on annual hours of use. This was used in the computation of depreciation cost.

$$\text{Depreciation} = \frac{(1 - SV/100) \times PP}{20.3 - (2 \times AP)/(10 \times C)}$$

$$\text{Investment} = \frac{PP \times (1 + SV/100) \times 0.10}{2}$$

$$\text{Insurance \& Housing} = PP \times 1\%$$

Where: SV = Salvage Value (%)

PP = Purchase Price ($)

AP = Annual Production (lb/yr)

C = Conveyor Capacity (lb/h)

Repair Costs: The Custom and Rental Guide (page 30) estimates repair costs for grain augers at 2% of purchase price per year. Assuming a 15 year life, it was calculated that over a depreciate life, 30% of a conveyor's value will be spent on repairs. This information was used together with the conveyor life time formula to compute repair costs in $/yr, as follows:

$$\text{Repair Costs} = \frac{0.3 \times PP}{20.3 - (2 \times AP)/(10 \times C)}$$

Where: PP = Purchase Price ($)

AP = Annual Production (lb/yr)

C = Capacity (lb/h)

Labour Cost: Once operating, conveyors do not need close attention. However, the labourer must wait for the product to be conveyed and can usually not do other work while doing so. Conveyors with low capacity will require more time and therefore more labour cost to move a given amount of product than ones with high capacity. Labour cost in $/yr has been computed using the following equation.

$$\text{Labour Cost} = \frac{LR \times AP \times 2}{C}$$

Where: LR = Labour Rate ($/h)

AP = Annual Production (lb/yr)

C = Conveyor Capacity (lb/h)

The farm labour rate of $9.00/hr from page 3 of the Custom and Rental Guide has been used in these computations.

5. RESULTS AND DISCUSSION

5.1 DAMAGE

FIGURES 5 through 7 illustrate the results of the damage tests. Data tables from the tests appear in APPENDIX III. This data has been adjusted to account for the different lengths of the test conveyors. Each is presented on the basis of a 40 ft (12.2 m) conveyor length.

Before reviewing the tests results, it is useful to know the relative accuracy of grain damage measurements. These measurements are made by visually inspecting crop samples from each test and separately weighing any damaged seeds.

Visual inspection is sometimes a highly subjective method of analysis. As well, seed damage within a batch of crop is subject to considerable variation. This can only be reduced by using large test samples. Because this is time consuming, a compromise must usually be reached regarding sample size. The reader should therefore be guided in not attempting to draw conclusions which are too precise for the data to support.

FIGURE 5 shows the damage in Century Peas at 13% moisture content resulting from one pass through each conveyor. The screw conveyor with steel flighting had the highest damage, ranging from 2.7% to 2.8% depending on conveyor elevation. The paddle conveyor was next highest ranging from 0.5% to 0.9%. The screw conveyor with bristle flighting gave lower damage, ranging from 0.2% to 0.7%. The belt conveyor was lowest with 0.2% damage.

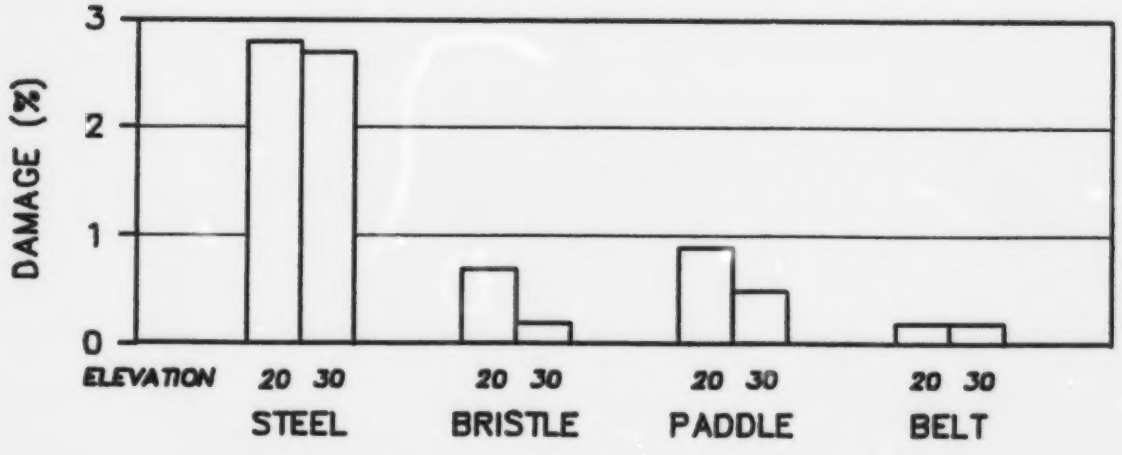


FIGURE 5. Damage in Century Peas at 13% Moisture Content.

FIGURE 6 shows the damage in Laird Lentils at a moisture content of 12.8% resulting from one pass through each conveyor. Again, the screw conveyor with steel flighting had the highest damage ranging from 1.8% to 2.6% depending on elevation. The screw conveyor with bristle flighting gave next highest damage, ranging from 0.6% to 1.3%. The paddle and belt conveyors were lowest with damage ranging from 0.4% to 1.0%.

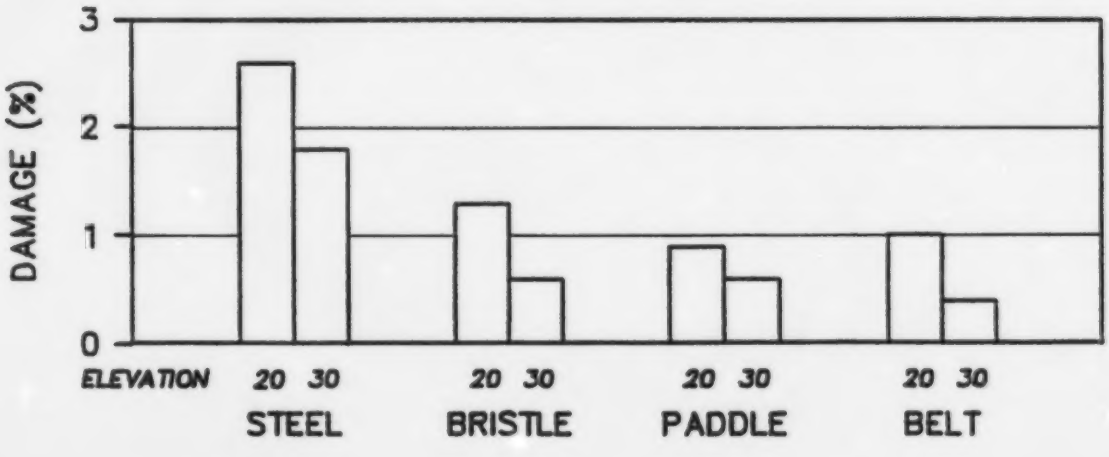


FIGURE 6. Damage in Laird Lentils at 12.8% Moisture Content.

FIGURE 7 shows the damage in Laird Lentils at a moisture content of 15.4% resulting from one pass through each conveyor. There was little difference in damage between the conveyors at this moisture content. The screw conveyor with bristle flighting gave highest damage ranging from 0.3% to 0.7%. The screw conveyor with steel flighting was next highest with damage ranging from 0.2% to 0.5%. The paddle and belt conveyors were lowest with damage ranging from 0.1% to 0.3%.

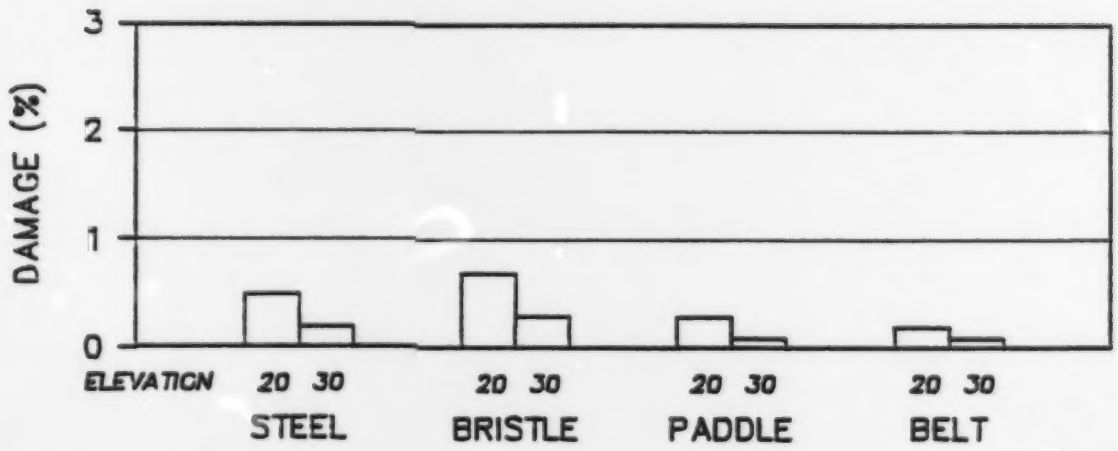


FIGURE 7. Damage in Laird Lentils at 15.4% Moisture Content.

FIGURES 5 through 7 show damage for each conveyor at two different elevations. The data indicates that, overall, each conveyor had a small decrease in damage with increased elevation. However, the small damage difference together with the limited accuracy of the data does not warrant drawing any precise conclusions.

Damage tests were conducted at two different conveyor speeds in Laird Lentils at 15.4% moisture content. The test data is shown in APPENDIX III. Damage from all conveyors was low in this test and no trend is obvious toward increased or decreased damage with changes in conveyor speed. Project scope limitations did not allow study of speed effects in the other crop conditions where considerable damage differences may have been discovered. This may be a worthwhile subject of future investigation.

5.2 CAPACITY

FIGURES 8 through 10 illustrate the capacity characteristics of the four conveyors in the three tests crops. In all three crops the paddle conveyor had the highest capacity followed by the steel flighting, belt and then bristle flighting conveyors, in order of decreasing capacity. The capacities of the steel flighting, belt and bristle flighting conveyors were respectively about 85%, 65% and 50% of the paddle conveyor's capacity.

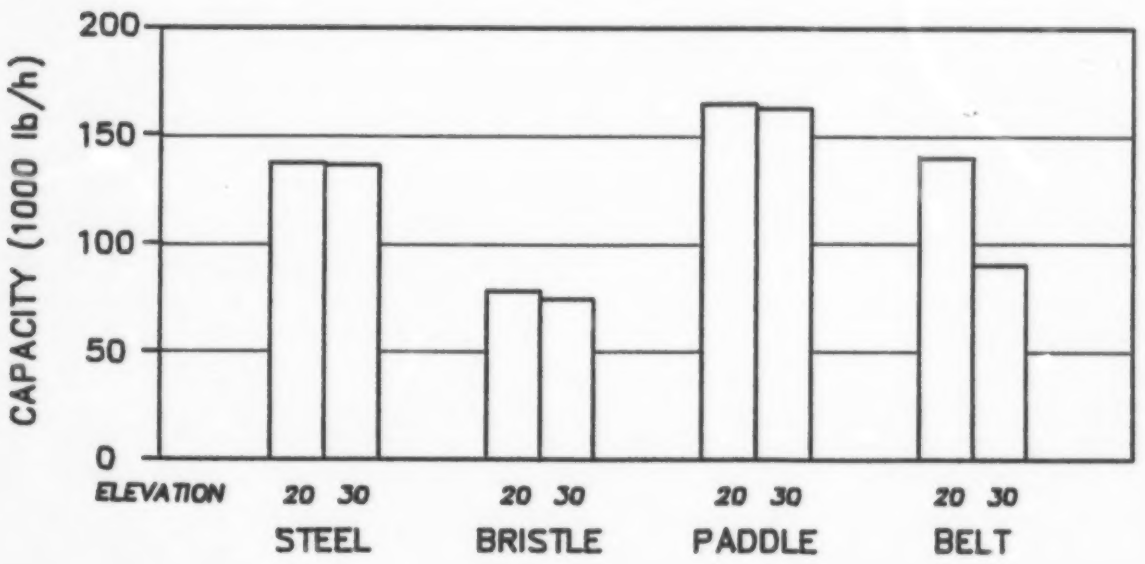


FIGURE 8. Capacity of Conveyors in Century Peas at 13% Moisture Content.

All three figures show capacity at 20° and 30° conveyor elevations. FIGURES 8 and 9 show that in dryer crop material, capacity of the belt conveyor decreased about 35% with elevation increase from 20° to 30°. In the same conditions, capacity of the other three conveyors decreased only slightly if at all.

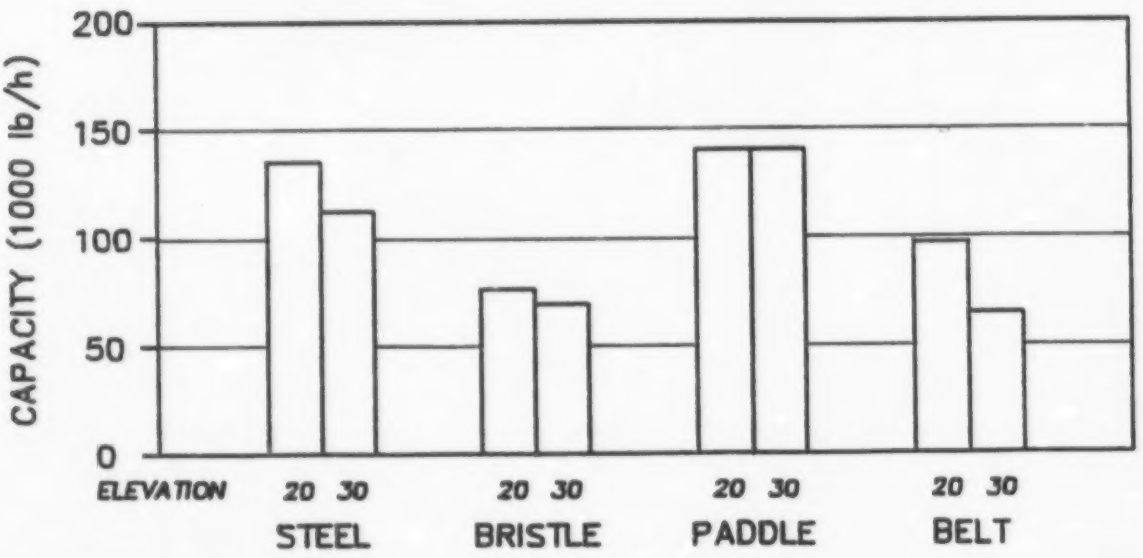


FIGURE 9. Capacity of Conveyors in Laird Lentils at 12.8% Moisture Content.

In crop with higher moisture content (FIGURE 10) all conveyors lost capacity as elevation increased. The belt conveyor lost most at about 30%. The steel flighting, paddle and bristle flighting conveyors lost 9%, 14% and 20% respectively with elevation increase from 20° to 30°. Decreases in conveyor capacity are usually caused by material slippage on the conveying device (flighting, paddle, belt, etc.)

Generally, the capacity of the paddle conveyor and belt conveyor continued to rise as the PTO speed increased. Whereas, the capacity of the steel and bristle screw conveyors peaked at a PTO speed of about 400 to 500 rpm.

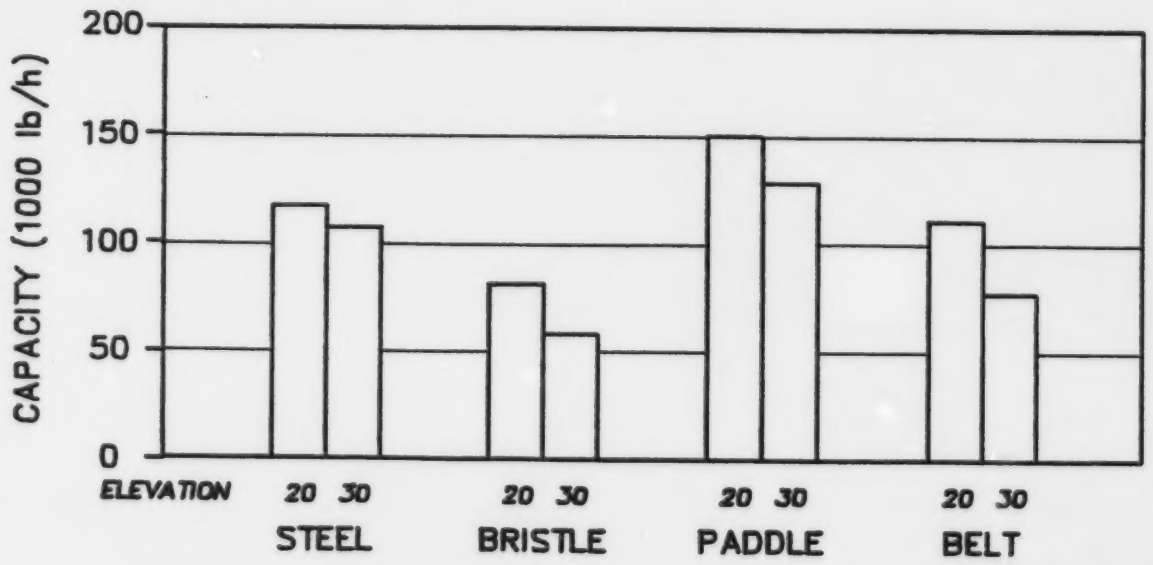


FIGURE 10. Capacity of Conveyors in Laird Lentils at 15.4% Moisture Content.

5.3 SPECIFIC CAPACITY

FIGURES 11 through 13 illustrate the specific capacity characteristics of each conveyor in the three crop conditions. Specific capacity is a measure of how much material a conveyor can move for a given energy input. It can be used to compare the relative efficiencies of the various conveyors. Specific capacity was computed from capacity data (APPENDIX IV) and power data (APPENDIX V). The data has been adjusted to account for the different test machine lengths and is presented on the basis of a conveyor length of 40 ft (12.2 m).

FIGURES 11 and 12 show that in the dryer crop materials, the paddle and belt conveyors were about equal and gave the highest specific capacities. The steel and bristle flighting conveyors had about 55% and 25% (respectively) of the efficiency of the paddle and belt conveyors.

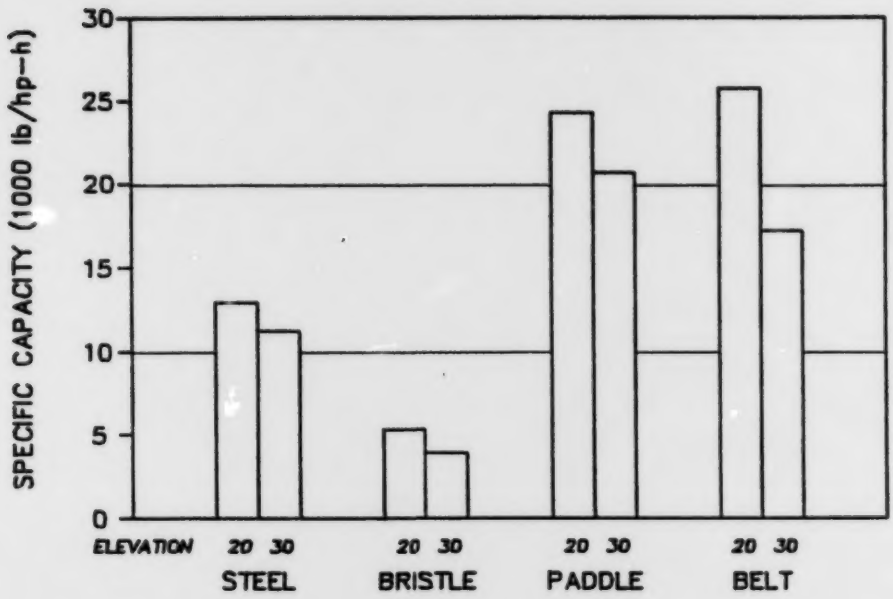


FIGURE 11. Specific Capacity in Century Peas at 13% Moisture Content.

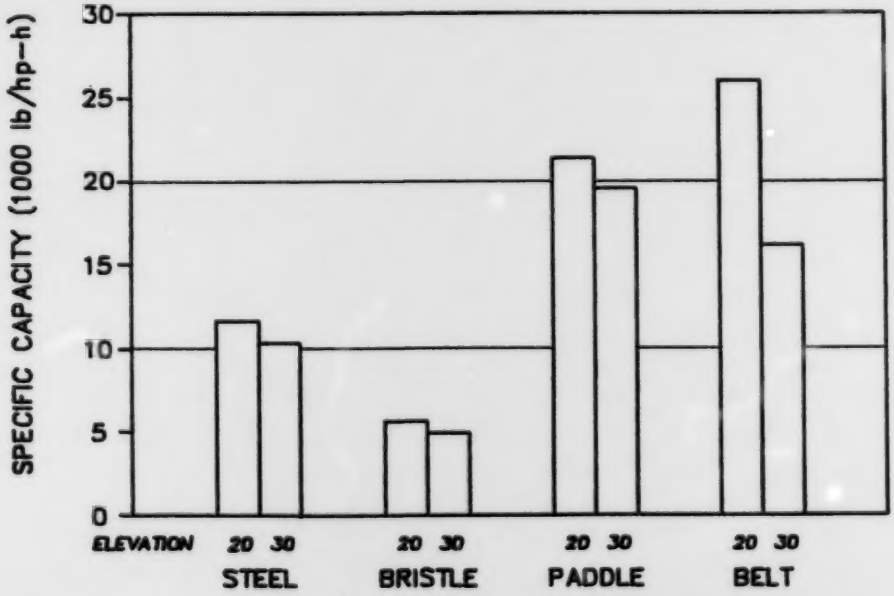


FIGURE 12. Specific Capacity in Laird Lentils at 12.8% Moisture Content.

FIGURE 13 shows that in lentils at the higher moisture content, the specific capacity of the paddle conveyor decreased somewhat while the belt conveyor remained unchanged. The steel and bristle flighting conveyors and the paddle conveyor respectively were 40%, 20% and 70% of the efficiency of the belt conveyor in this crop and moisture content.

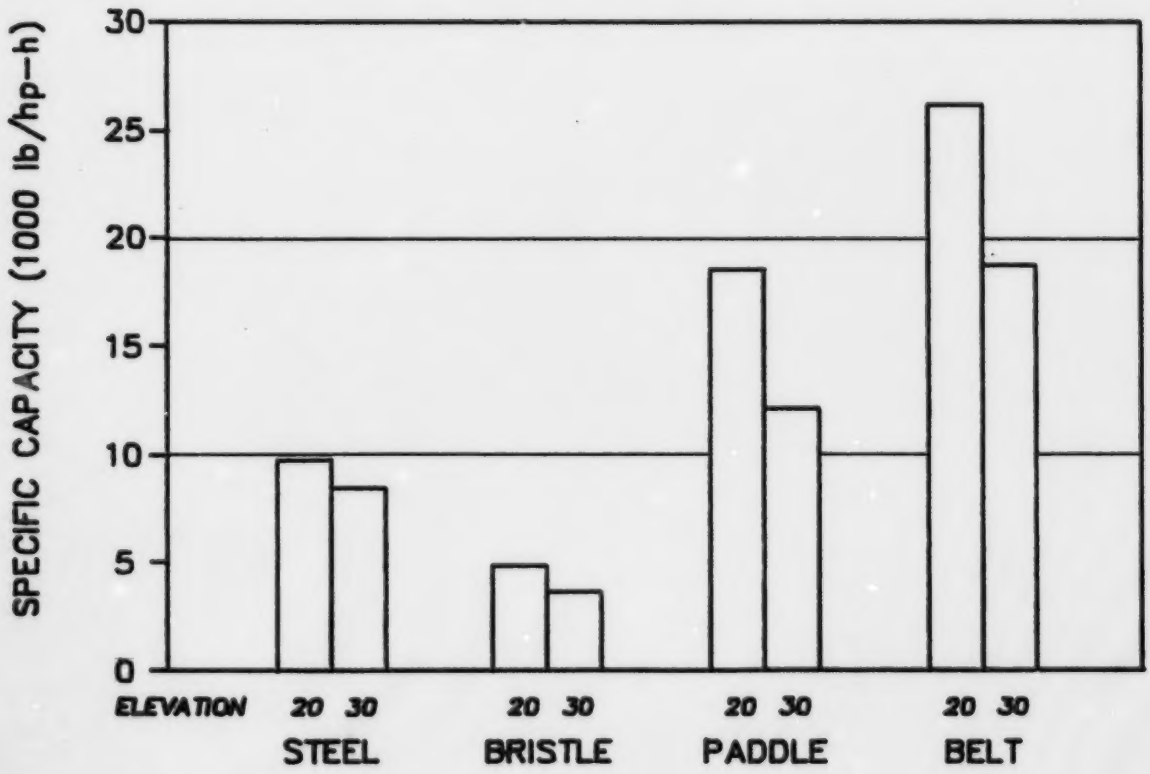


FIGURE 13. Specific Capacity in Laird Lentils at 15.4% Moisture Content.

FIGURES 11 through 13 show that conveyor elevation changes from 20^{o} to 30^{o} did not greatly affect the specific capacity of the steel and bristle flighting conveyors. The paddle conveyor was only affected by the elevation change when operating in the higher moisture lentils, where a 35% reduction in specific capacity occurred. For the belt conveyor, a 35% reduction in specific capacity occurred in all crops and conditions with elevation increase from 20^{o} to 30^{o}.

5.4 ECONOMIC ANALYSIS

TABLES 1 through 3 give a breakdown of conveying costs, based on an annual production of 200,000 lb (90,900 kg). The inputs used for the economic analysis together with conveying cost tables for the range from 0 to 400,000 lb/yr (181,800 kg/yr) are shown in APPENDIX VI.

TABLE 1 shows that total conveying costs in Century Peas at 13% moisture content ranged from about $510 to $754 depending on conveyor type. Under current prices this would amount to about 3% of the revenue generated from the crop. Costs arising from damage ranged from 2% to 43% of total conveying costs depending on conveyor type.

TABLE 1. Conveying Costs in Century Peas at 13.0% Moisture Content. [Annual Production of 200,000 lb (90,900 kg)]

Conveyor Type	Power Cost $/yr	Fixed Cost $/yr	Repair Cost $/yr	Grain Damage $/yr	Labour Cost $/yr	Total Cost $/yr
Steel Flighting	8.49	223.40	30.46	221.61	26.32	510.27
Bristle Flighting	24.19	393.78	54.06	58.04	48.00	578.07
Paddle	4.65	505.40	68.81	74.54	22.06	675.46
Belt	5.55	608.34	83.30	16.62	40.00	753.80

Although there were considerable differences in damage characteristics between conveyors, they did not translate to overall economic differences. This was because, under present market conditions, damage caused very little reduction in value to peas. Usually, fixed costs were larger than damage costs. Under these conditions, the screw conveyor with steel flighting, because of its low purchase price, gave the lowest total conveying cost. The bristle flighting conveyor was next lowest, while the paddle and belt conveyors were highest.

TABLE 2 shows total conveying costs in Laird Lentils at 12.8% moisture content. Total costs ranged from about $2,353 to $7,430 depending on conveyor type. Under current prices this amounts from 8% to 22% of revenue generated from the crop. For all conveyors, damage costs considerably outweighed all others, ranging from 68% to 96% of total conveying costs.

TABLE 2. Conveying Costs in Laird Lentils at 12.8% Moisture Content. [Annual Production of 200,000 lb (90,900 kg)]

Conveyor Type	Power Cost $/yr	Fixed Cost $/yr	Repair Cost $/yr	Grain Damage $/yr	Labour Cost $/yr	Total Cost $/yr
Steel Flighting	9.22	223.69	30.55	7,135.20	31.72	7,430.38
Bristle Flighting	19.23	394.12	54.16	2,392.80	51.52	2,911.84
Paddle	4.96	505.81	68.94	2,392.80	25.45	2,997.96
Belt	5.92	610.65	84.03	1,596.80	55.52	2,352.92

The belt conveyor had the best economic performance, even though its fixed and repair costs were higher, because it caused least damage. The screw conveyor with bristle flighting and the paddle conveyor gave next best performance and were approximately equal. The screw conveyor with steel flighting had highest total conveying cost, at about three times that of the belt conveyor.

TABLE 3 shows that total conveying costs in Laird Lentils at 15.4% moisture content ranged from about $1,011 to $2,294 depending on conveyor type. This would amount from 3% to 7% of revenue from the crop at current prices. Costs arising from damage accounted from 35% to 87% of total conveying costs.

TABLE 3. Conveying Costs in Laird Lentils at 15.4% Moisture Content [Annual Production of 200,000 lb (90,900 kg)].

Conveyor Type	Power Cost $/yr	Fixed Cost $/yr	Repair Cost $/yr	Grain Damage $/yr	Labour Cost $/yr	Total Cost $/yr
Steel Flighting	11.25	223.78	30.58	1,995.00	33.49	2,294.10
Bristle Flighting	26.14	395.07	54.46	1,198.20	61.28	1,735.16
Paddle	7.98	506.12	69.04	399.80	27.96	1,010.89
Belt	5.16	609.24	83.58	399.80	46.08	1,143.85

The belt and paddle conveyors were about equal and had best economic performance, because they caused least damage. The screw conveyor with bristle flighting had next higher cost while the one with steel flighting had the highest cost.

5.5 OTHER CONSIDERATIONS

While operating the conveyors during testing, a number of observations were made that could affect a buyer's decision.

Firstly, it was noted that some contamination took place between crops when using the screw conveyors. This happened even though the conveyors were run for several minutes after a crop was conveyed to clean it out. At the inlet of the bristle flighting seeds were observed stuck between the nylon bristles and were difficult to remove. This contamination could potentially be a problem for seed producers and other pulse crop processors.

Also, on the bristle flighting, some plugging occurred at the lower PTO speeds. Once plugging occurred, the shear pin on the auger drive broke. To correct the problem, the flighting had to be turned backwards until the crop was cleaned out and the shear pin replaced.

When performing the power and capacity tests, the grain was dropped into a wagon sitting on the ground. At 30^{o} elevation angle this drop height ranged from 17 to 27 ft (5.2 to 8.2 m). It was observed that damage occurred when the crops were dropped this great height. Some producers and processors are presently using bean ladders which drop the crop in a series of steps to the granary floor. It is recommended that further study take place to determine what maximum drop height can be used safely when conveying pulse crops. As well, a study of different impact surfaces and means of reducing drop height should also take place.

6. CONCLUSIONS

Crop Damage: Handling of pulse crops with any conveyor should be avoided whenever possible as some damage will occur. In both overdry pulse crops, the screw conveyor with steel flighting gave damage from 2% to 3% while damage by the others was often much less than 1%. In lentils at 15.4% moisture content, the four conveyors usually caused less than 0.5% damage with the paddle and belt conveyors as low as 0.1%. These tests showed that one effective way of reducing damage was conveying the crop at a higher moisture content. This should be kept in mind at all times during harvest and drying of pulse crops.

Capacity: Capacity of the paddle conveyor was highest followed by the steel flighting, belt and bristle flighting conveyors respectively. Flood feeding the inlets of the conveyors was important in maximizing the capacity and minimizing the damage.

Specific Capacity: The belt conveyor had highest specific capacity (efficiency of power usage) in all crops and conditions. In the overdry peas and lentils the paddle conveyor nearly equaled the efficiency of the belt conveyor but decreased to about 70% of the paddle conveyor in the damper lentils. The screw conveyors with steel and bristle flighting respectively had about 50% and 25% of the efficiency of the belt conveyor.

Economic Analysis: For pulse crops such as peas where damage may not substantially affect price, a low-cost conveyor would be best from an economic point of view. However, in all cases where damage even moderately affects pulse crop price, a conveyor with low damage characteristics will save a producer considerable money even though its purchase cost may be higher.

SUMMARY REPORT

Under funding provided by Saskatchewan Agriculture (through the Agriculture Development Fund), the Saskatchewan Pulse Crop Development Board and the Saskatchewan and Manitoba Wheat Pools, a study was done to compare four unique conveyors in pulse crops. They were compared for crop damage, capacity and specific capacity while conveying lentils at two moisture contents and peas at one moisture content.

The crop damage comparison generally showed that for both crops at about 13% moisture content, the steel flighting screw conveyor to have the highest damage at 2% to 3%. The paddle, bristle flighting and belt conveyors were usually much less than 1% under these conditions. In lentils at 15.4% moisture content, the four conveyors usually gave less than 0.5% damage with the paddle and belt conveyors as low as 0.1%.

Generally, the paddle conveyor had the highest peak capacity followed by the steel flighting, belt and bristle flighting conveyors respectively. Capacity in all conveyors dropped as elevation angles increased. The capacity of the paddle and belt conveyors continued to rise as the PTO speed increased. The steel and bristle flighting capacity peaked at a PTO speed of about 400 to 500 rpm.

The belt conveyor had highest specific capacity (efficiency of power usage) in all crops and conditions. In the overdry peas and lentils the paddle conveyor nearly equaled the efficiency of the belt conveyor but decreased to about 70% of the paddle conveyor in the

damper lentils. The screw conveyors with steel and bristle flighting respectively had about 50% and 25% of the efficiency of the belt conveyor.

For pulse crops such as peas where damage may not substantially affect price, a low-cost conveyor would be best from an economic point of view. However, in all cases where damage even moderately affects pulse crop price, a conveyor with low damage characteristics will save a producer considerable money even though its purchase cost may be higher.

PROPOSED PUBLICATIONS

1. SUMMARY REPORT

Results from this study will be presented in a summary report which will be mailed to approximately 11,000 PAMI subscribers across the prairies. These summary reports will also be available to any producers who request them.

2. NEWS RELEASES

News Releases of the results will be sent to prairie newspapers for publication.

3. TEST STANDARD

A detailed test procedure on grain augers has been written and will be further developed to be the basis of testing of the other conveyors used in this study.

EXPENDITURES

(As of March 31, 1989)

ALLOCATION	BUDGET	ACTUAL COSTS						
		ADF	SPCDB	SWP	MPE	PAMI	MFTRS	TOTAL
SALARIES								
- Professional	$ 9,760	$2,086	$2,086	$1,531	$ 557	$ 8,614		$14,874
- Technical	13,380	4,460	4,460	3,271	1,189	976		14,356
EQUIPMENT								
- Rental	4,250	167	167	121	45	3,750		4,250
MATERIALS	1,830	569	569	416	151	97		1,802
TRAVEL	530	218	218	161	58			665
TEST MACHINE USAGE	2,200					856	$1,344	2,200
PRINTING COSTS	1,000					125		125
TOTAL	$32,950	$7,500	$7,500	$5,500	$2,000	$14,418	$1,344	$38,262

Funding Sources

ADF: Agriculture Development Fund
SPCDB: Saskatchewan Pulse Crop Development Board
SWP: Saskatchewan Wheat Pool
MPE: Manitoba Pool Elevators
PAMI: Prairie Agricultural Machinery Institute
MFTRS: Participating Manufacturers (See Acknowledgments)

PERSONNEL

(As of March 31, 1989)

NAME	PORTION OF TIME (%) **
Engineers	
- Doug May (PAMI)	28%
- David Gullacher (PAMI)	1%
- Hughie Kydd (PAMI)	1%
Technologists	
- Ken Carmichael (PAMI)	9%
- Bob Harris (PAMI)	20%
- Dan Dyck (PAMI)	16%
- Murray Lone (PAMI)	1%

NOTES:

* Time so marked was donated free-of-charge to the project.

** This project ran for about 126 working days. The portion of time each person spent on the project is expressed as a percentage of this time.

EQUIPMENT PURCHASED

No equipment was purchased for purposes of conducting this project. Required equipment was either lent by PAMI or rented from suppliers.

APPENDIX I

TERMINOLOGY

Capacity: Volume (bu/h) (m^3/h) or Mass (t/h) or [t/h] or (lb/l) [kg/h] of crop material conveyed per unit of time.

Crop Damage: Deterioration of seed caused by mechanical conveying. Includes peeled, split and broken pieces that are less than three quarters of the whole seed and halves that are loosely held together by the seed coats.

Flighting: Helicoid shaped steel ribbon with solid core, used to move granular material.

Moisture Content: The amount of water as a percentage (%) of the total weight of dry matter and water. Moisture content expressed this way is termed "wet basis".

Power Requirement: Power supplied through input shaft of conveyor. This is the actual power required by each conveyor to overcome friction and move the material in the conveyor.

Specific Requirements: The amount of grain moved per unit of power in a specific time (lb/hp-h) (t/kw-h).

APPENDIX II

REFERENCES

Bouse, L. F., Schoenleber, L. G. and Porterfield, J. G., Screw Conveyor Capacity and Castor Seed Damage, ASAE Paper No. 62-816, American Society of Agricultural Engineers, St. Joseph, MI, 1964.

Fiscus, D. E., Foster, G. H. and Kaufmann, H. H., Physical Damage of Grain Caused by Various Handling Techniques, ASAE Paper No. 69-853, American Society of Agricultural Engineers, St. Joseph, MI, 1971.

Misra, M. K. and Bern, C. J., Evaluation of Nylon Bristle Auger for Handling of Soybean Seed, ASAE Paper No. 82-3568, American Society of Agricultural Engineers, St. Joseph, MI, 1982.

Sands, L. D and Hall, G. E., Damage to Shelled Corn During Transport in a Screw Conveyor, ASAE Paper No. 69-826, American Society of Agricultural Engineers, St. Joseph, MI, 1971.

APPENDIX III

Crop Damage in Century Peas at 13% Moisture Content

Conveyor	Angle (Degrees)	Damage %
Steel Flighting	20	2.8
	30	2.7
Bristle Flighting	20	0.2
	30	0.7
Paddle Conveyor	20	0.5
	30	0.9
Belt Conveyor	20	0.2
	30	0.2

Crop Damage in Laird Lentils at 12.8% Moisture Content

Conveyor	Angle (Degrees)	Damage %
Steel Flighting	20	2.6
	30	1.8
Bristle Flighting	20	1.3
	30	0.6
Paddle Conveyor	20	0.9
	30	0.6
Belt Conveyor	20	1.0
	30	0.4

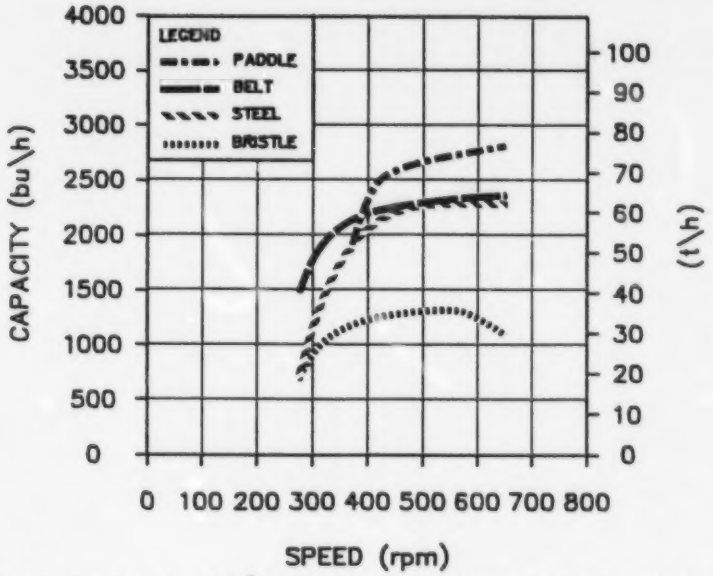
APPENDIX III - (Continued)

Crop Damage in Laird Lentils at 15.4% Moisture Content

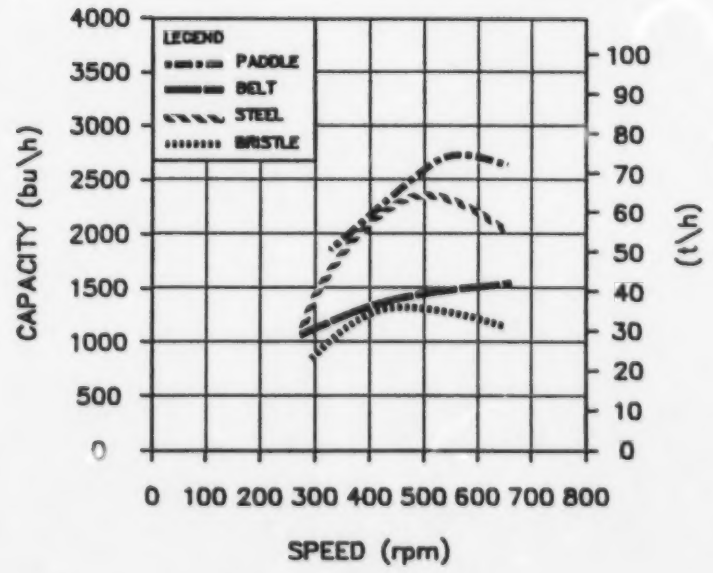
Conveyor	Angle (Degrees)	PTO Speed (RPM)	Damage %
Steel Flighting	20	270	0.4
	30	270	0.7
	20	540	0.2
	30	540	0.5
Bristle Flighting	20	270	0.8
	30	270	0.2
	20	540	0.7
	30	540	0.3
Paddle Conveyor	20	270	0.2
	30	270	0.2
	20	540	0.3
	30	540	0.1
Belt Conveyor	20	270	0.0
	30	270	0.0
	20	540	0.2
	30	540	0.1

APPENDIX IV

Capacity Data Graphs

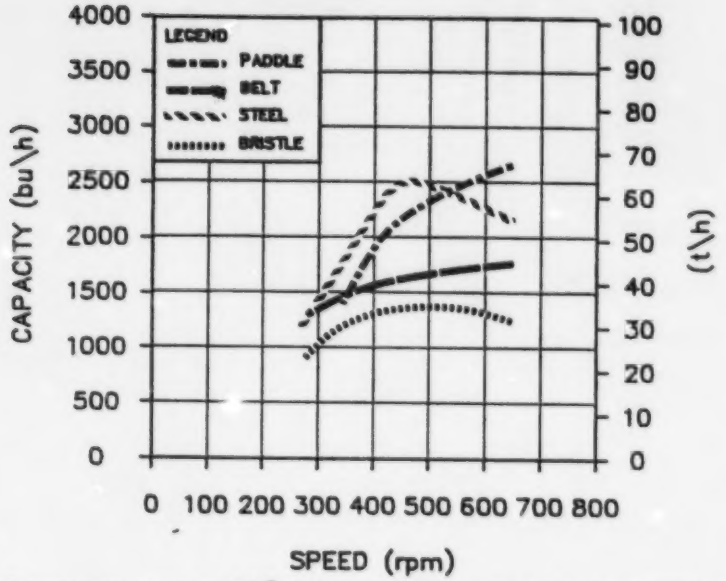


Capacity of Conveyors at 20° Elevation in Century Peas at 13% Moisture Content.

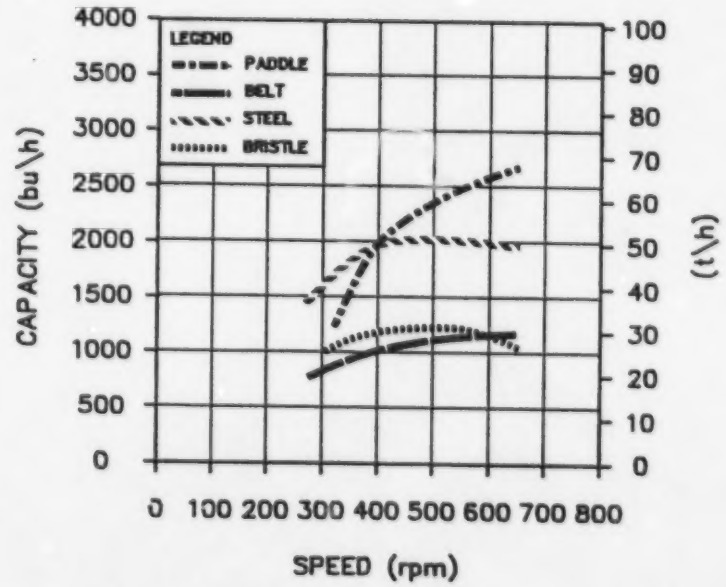


Capacity of Conveyors at 30° Elevation in Century Peas at 13% Moisture Content.

APPENDIX IV - (Continued)

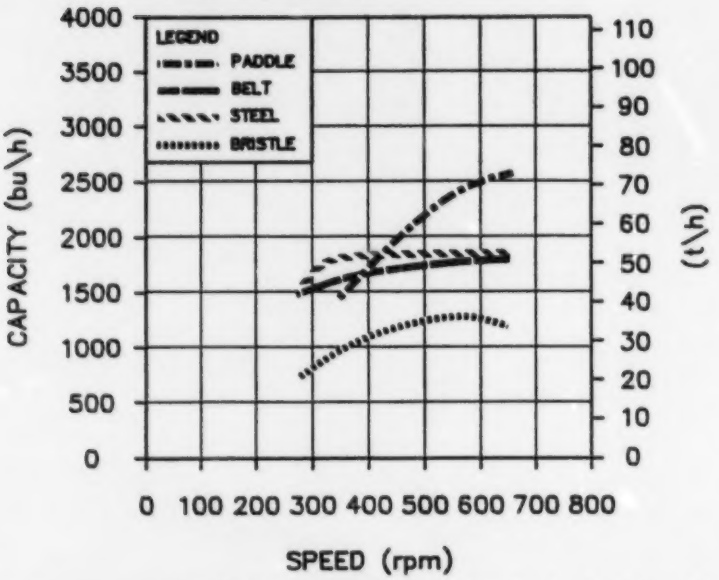


Capacity of Conveyors at 20° Elevation in Laird Lentils at 12.8% Moisture Content.

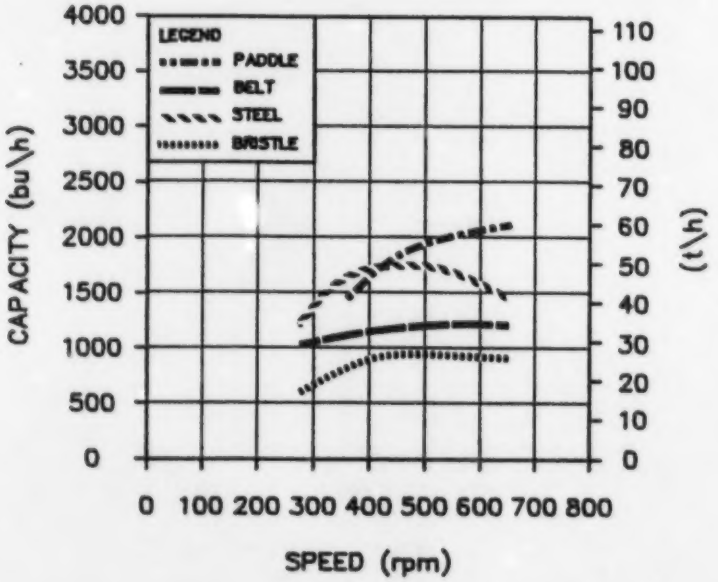


Capacity of Conveyors at 30° Elevation in Laird Lentils at 12.8% Moisture Content.

APPENDIX IV - (Continued)



Capacity of Conveyors at 20° Elevation in Laird Lentils at 15.4% Moisture Content.



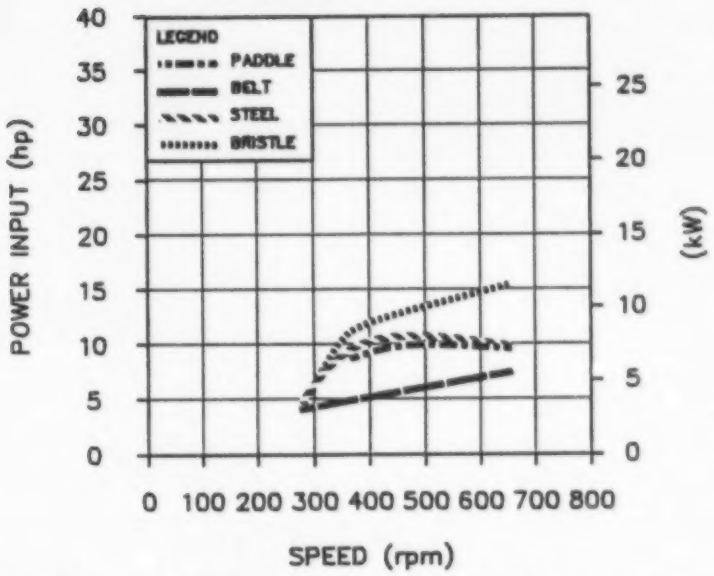
Capacity of Conveyors at 30° Elevation in Laird Lentils at 15.4% Moisture Content.

APPENDIX V

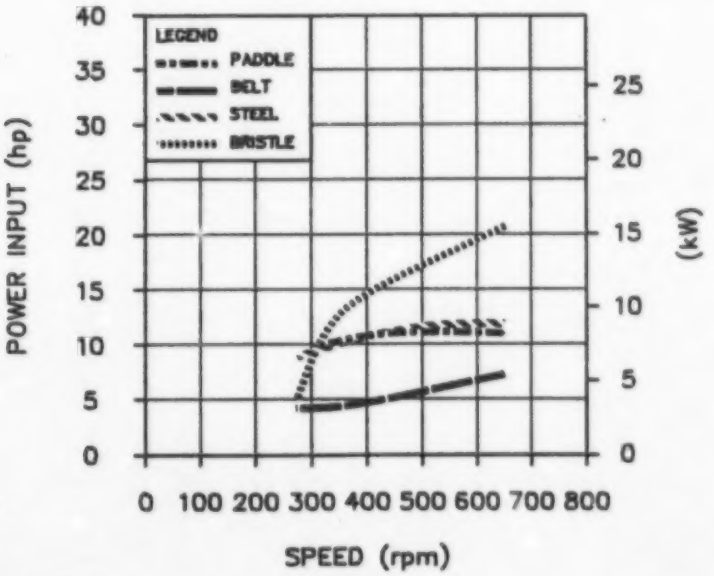
Power Data Graphs

Note: The power requirements shown here for the paddle and belt conveyors are for the conveyor lengths as tested (see Section 3). The data has not been adjusted to present each conveyor on a 40 ft (12.2 m) basis.

APPENDIX V - Continued

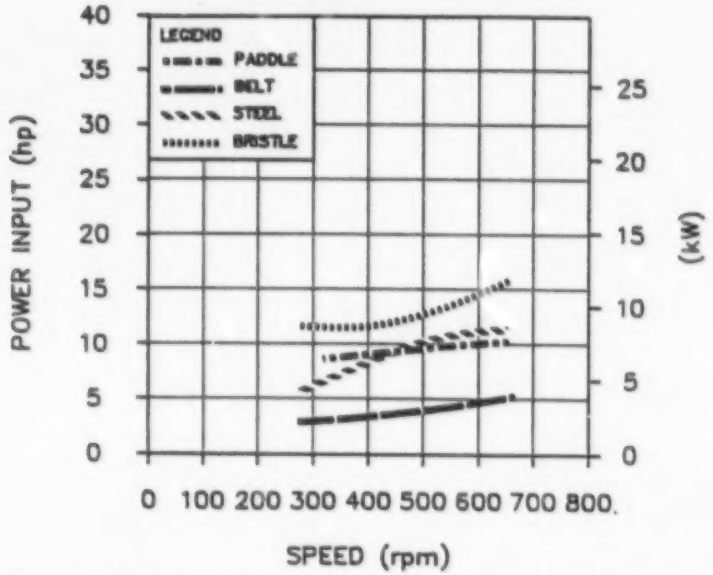


Power Requirements of Conveyors at 20° Elevation in Century Peas at 13% Moisture Content.

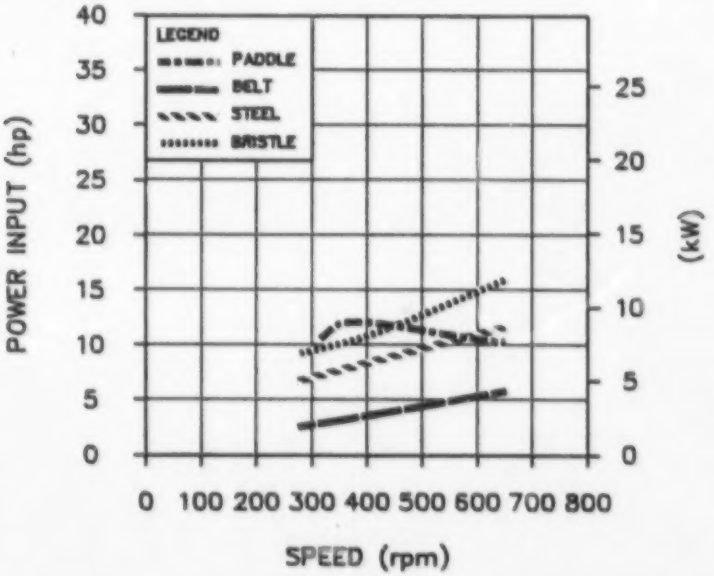


Power Requirements of Conveyors at 30° Elevation in Century Peas at 13% Moisture Content.

APPENDIX V - (Continued)

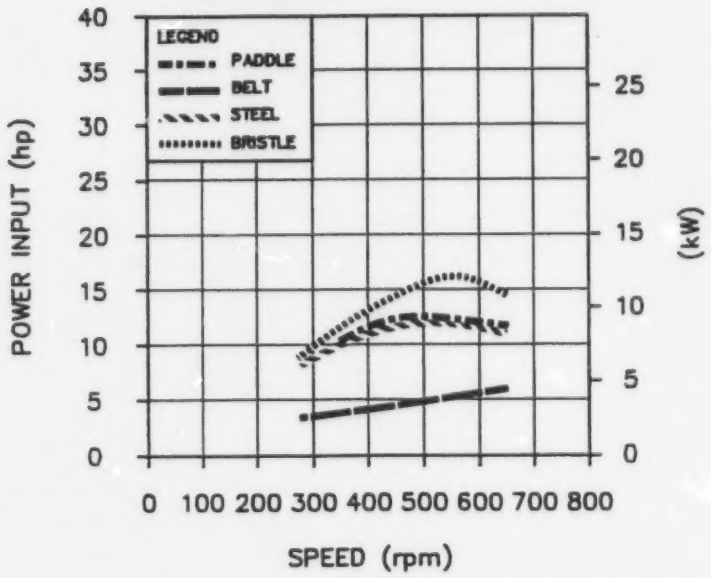


Power Requirements of Conveyors at 20° Elevation in Laird Lentils at 12.8% Moisture Content.

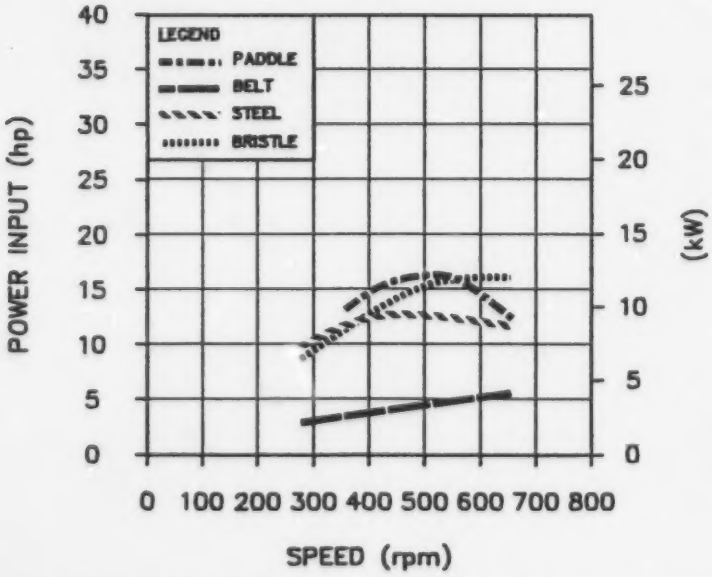


Power Requirements of Conveyors at 30° Elevation in Laird Lentils at 12.8% Moisture Content.

APPENDIX V - (Continued)



Power Requirements of Conveyors at 20° Elevation in Laird Lentils at 15.4% Moisture Content.



Power Requirements of Conveyors at 30° Elevation in Laird Lentils at 15.4% Moisture Content.

APPENDIX VI

Economic Analysis Calculation Tables

The following sheets show the inputs used to calculate the various conveying costs for each of the conveyor types in each crop and condition. For each scenario, a table is presented of conveying costs for various annual production rates ranging from 0 to 400,000 lb/yr (181,800 kg/yr).

SCREW CONVEYOR WITH STEEL FLIGHTING

INPUTS

CROP MATERIAL	PEAS
MOISTURE CONTENT (%)	13
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	136800
Power Requirements (hp)	12.1
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$2,031.20
Commodity Price ($/LB-%)	$0.02
Commodity Damage Rate (%)	2.7
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	222.01	30.02	0.00	0.00	$252.02
25000	1.06	222.18	30.07	27.70	3.29	$284.30
50000	2.12	222.35	30.13	55.40	6.58	$316.58
75000	3.18	222.52	30.18	83.10	9.87	$348.86
100000	4.25	222.70	30.24	110.80	13.16	$381.14
125000	5.31	222.87	30.29	138.50	16.45	$413.42
150000	6.37	223.04	30.35	166.21	19.74	$445.70
175000	7.43	223.22	30.40	193.91	23.03	$477.98
200000	8.49	223.40	30.46	221.61	26.32	$510.27
225000	9.55	223.57	30.51	249.31	29.61	$542.55
250000	10.61	223.75	30.57	277.01	32.89	$574.84
275000	11.68	223.93	30.62	304.71	36.18	$607.12
300000	12.74	224.11	30.68	332.41	39.47	$639.41
325000	13.80	224.28	30.74	360.11	42.76	$671.69
350000	14.86	224.46	30.79	387.81	46.05	$703.98
375000	15.92	224.64	30.85	415.51	49.34	$736.27
400000	16.98	224.83	30.91	443.21	52.63	$768.56

SCREW CONVEYOR WITH BRISTLE FLIGHTING

INPUTS

CROP MATERIAL	PEAS
MOISTURE CONTENT (%)	13
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	75000
Power Requirements (hp)	18.9
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$3,561.70
Commodity Price ($/LB-%)	$0.02
Commodity Damage Rate (%)	0.7
Labour Rate ($/h)	$9.00

CALCULATION TABLE (BRISTLE)

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	389.29	52.64	0.00	0.00	$441.92
25000	3.02	389.84	52.81	7.25	6.00	$458.92
50000	6.05	390.39	52.98	14.51	12.00	$475.93
75000	9.07	390.95	53.16	21.76	18.00	$492.94
100000	12.10	391.51	53.34	29.02	24.00	$509.96
125000	15.12	392.07	53.51	36.27	30.00	$526.98
150000	18.14	392.64	53.69	43.53	36.00	$544.00
175000	21.17	393.21	53.87	50.78	42.00	$561.03
200000	24.19	393.78	54.06	58.04	48.00	$578.07
225000	27.22	394.36	54.24	65.29	54.00	$595.11
250000	30.24	394.95	54.42	72.55	60.00	$612.16
275000	33.26	395.53	54.61	79.80	66.00	$629.21
300000	36.29	396.12	54.80	87.05	72.00	$646.26
325000	39.31	396.72	54.98	94.31	78.00	$663.32
350000	42.34	397.32	55.17	101.56	84.00	$680.39
375000	45.36	397.92	55.36	108.82	90.00	$697.46
400000	48.38	398.53	55.56	116.07	96.00	$714.54

PADDLE CONVEYOR

INPUTS

CROP MATERIAL	PEAS
MOISTURE CONTENT (%)	13
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	163200
Power Requirements (hp)	7.9
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$4,600.00
Commodity Price ($/LB-%)	$0.02
Commodity Damage Rate (%)	0.9
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	502.77	67.98	0.00	0.00	$570.75
25000	0.58	503.10	68.08	9.32	2.76	$583.84
50000	1.16	503.42	68.19	18.64	5.51	$596.92
75000	1.74	503.75	68.29	27.95	8.27	$610.01
100000	2.32	504.08	68.39	37.27	11.03	$623.10
125000	2.90	504.41	68.50	46.59	13.79	$636.19
150000	3.49	504.74	68.60	55.91	16.54	$649.28
175000	4.07	505.07	68.71	65.23	19.30	$662.37
200000	4.65	505.40	68.81	74.54	22.06	$675.46
225000	5.23	505.74	68.92	83.86	24.82	$688.56
250000	5.81	506.07	69.02	93.18	27.57	$701.65
275000	6.39	506.41	69.13	102.50	30.33	$714.75
300000	6.97	506.74	69.23	111.81	33.09	$727.85
325000	7.55	507.08	69.34	121.13	35.85	$740.95
350000	8.13	507.42	69.45	130.45	38.60	$754.05
375000	8.71	507.76	69.55	139.77	41.36	$767.15
400000	9.29	508.10	69.66	149.09	44.12	$780.26

BELT CONVEYOR

INPUTS

CROP MATERIAL	PEAS
MOISTURE CONTENT (%)	13
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	90000
Power Requirements (hp)	5.2
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$5,513.00
Commodity Price ($/LB-%)	$0.02
Commodity Damage Rate (%)	0.2
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	602.56	81.47	0.00	0.00	$684.03
25000	0.69	603.27	81.70	2.08	5.00	$692.74
50000	1.39	603.98	81.92	4.16	10.00	$701.44
75000	2.08	604.70	82.15	6.23	15.00	$710.16
100000	2.77	605.42	82.37	8.31	20.00	$718.88
125000	3.47	606.14	82.60	10.39	25.00	$727.60
150000	4.16	606.87	82.83	12.47	30.00	$736.33
175000	4.85	607.60	83.06	14.55	35.00	$745.06
200000	5.55	608.34	83.30	16.62	40.00	$753.80
225000	6.24	609.08	83.53	18.70	45.00	$762.55
250000	6.93	609.82	83.77	20.78	50.00	$771.30
275000	7.63	610.57	84.00	22.86	55.00	$780.05
300000	8.32	611.32	84.24	24.94	60.00	$788.81
325000	9.01	612.08	84.48	27.01	65.00	$797.58
350000	9.71	612.84	84.72	29.09	70.00	$806.36
375000	10.40	613.60	84.96	31.17	75.00	$815.13
400000	11.09	614.37	85.20	33.25	80.00	$823.92

SCREW CONVEYOR WITH STEEL FLIGHTING

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	12.8
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	113480
Power Requirements (hp)	10.9
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$2,031.20
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	1.8
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	222.01	30.02	0.00	0.00	$252.02
25000	1.15	222.21	30.08	891.90	3.97	$1,149.31
50000	2.31	222.42	30.15	1783.80	7.93	$2,046.61
75000	3.46	222.63	30.21	2675.70	11.90	$2,943.90
100000	4.61	222.84	30.28	3567.60	15.86	$3,841.19
125000	5.76	223.05	30.35	4459.50	19.83	$4,738.49
150000	6.92	223.26	30.41	5351.40	23.79	$5,635.78
175000	8.07	223.47	30.48	6243.30	27.76	$6,533.08
200000	9.22	223.69	30.55	7135.20	31.72	$7,430.38
225000	10.37	223.90	30.62	8027.10	35.69	$8,327.68
250000	11.53	224.12	30.68	8919.00	39.65	$9,224.98
275000	12.68	224.33	30.75	9810.90	43.62	$10,122.28
300000	13.83	224.55	30.82	10702.80	47.59	$11,019.59
325000	14.98	224.77	30.89	11594.70	51.55	$11,916.89
350000	16.14	224.99	30.96	12486.60	55.52	$12,814.20
375000	17.29	225.21	31.03	13378.50	59.48	$13,711.50
400000	18.44	225.43	31.10	14270.40	63.45	$14,608.81

SCREW CONVEYOR WITH BRISTLE FLIGHTING

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	12.8
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	69880
Power Requirements (hp)	14
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$3,561.70
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.6
Labour Rate ($/h)	$9.00

CALCULATION TABLE (BRISTLE)

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	389.29	52.64	0.00	0.00	$441.92
25000	2.40	389.88	52.82	299.10	6.44	$750.64
50000	4.81	390.47	53.01	598.20	12.88	$1,059.37
75000	7.21	391.07	53.20	897.30	19.32	$1,368.10
100000	9.62	391.67	53.39	1196.40	25.76	$1,676.83
125000	12.02	392.28	53.58	1495.50	32.20	$1,985.58
150000	14.42	392.89	53.77	1794.60	38.64	$2,294.32
175000	16.83	393.50	53.97	2093.70	45.08	$2,603.08
200000	19.23	394.12	54.16	2392.80	51.52	$2,911.84
225000	21.64	394.75	54.36	2691.90	57.96	$3,220.60
250000	24.04	395.38	54.56	2991.00	64.40	$3,529.37
275000	26.45	396.01	54.76	3290.10	70.84	$3,838.15
300000	28.85	396.65	54.96	3589.20	77.28	$4,146.93
325000	31.25	397.29	55.16	3888.30	83.71	$4,455.72
350000	33.66	397.94	55.37	4187.40	90.15	$4,764.52
375000	36.06	398.59	55.57	4486.50	96.59	$5,073.32
400000	38.47	399.25	55.78	4785.60	103.03	$5,382.13

PADDLE CONVEYOR

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	12.8
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	141430
Power Requirements (hp)	7.3
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$4,600.00
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.6
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	502.77	67.98	0.00	0.00	$570.75
25000	0.62	503.15	68.10	299.10	3.18	$874.15
50000	1.24	503.52	68.22	598.20	6.36	$1,177.54
75000	1.86	503.90	68.34	897.30	9.55	$1,480.94
100000	2.48	504.28	68.46	1196.40	12.73	$1,784.34
125000	3.10	504.66	68.58	1495.50	15.91	$2,087.75
150000	3.72	505.04	68.70	1794.60	19.09	$2,391.15
175000	4.34	505.43	68.82	2093.70	22.27	$2,694.56
200000	4.96	505.81	68.94	2392.80	25.45	$2,997.96
225000	5.57	506.20	69.06	2691.90	28.64	$3,301.37
250000	6.19	506.59	69.19	2991.00	31.82	$3,604.78
275000	6.81	506.98	69.31	3290.10	35.00	$3,908.20
300000	7.43	507.37	69.43	3589.20	38.18	$4,211.61
325000	8.05	507.76	69.56	3888.30	41.36	$4,515.03
350000	8.67	508.15	69.68	4187.40	44.55	$4,818.45
375000	9.29	508.55	69.80	4486.50	47.73	$5,121.87
400000	9.91	508.94	69.93	4785.60	50.91	$5,425.29

BELT CONVEYOR

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	12.8
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	64840
Power Requirements (hp)	4
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$5,513.00
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.4
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	602.56	81.47	0.00	0.00	$684.03
25000	0.74	603.54	81.78	199.60	6.94	$892.61
50000	1.48	604.54	82.10	399.20	13.88	$1,101.19
75000	2.22	605.53	82.41	598.80	20.82	$1,309.79
100000	2.96	606.54	82.73	798.40	27.76	$1,518.39
125000	3.70	607.56	83.05	998.00	34.70	$1,727.01
150000	4.44	608.58	83.37	1197.60	41.64	$1,935.63
175000	5.18	609.61	83.70	1397.20	48.58	$2,144.27
200000	5.92	610.65	84.03	1596.80	55.52	$2,352.92
225000	6.66	611.69	84.36	1796.40	62.46	$2,561.57
250000	7.40	612.75	84.69	1996.00	69.40	$2,770.24
275000	8.14	613.81	85.03	2195.60	76.34	$2,978.92
300000	8.88	614.88	85.36	2395.20	83.28	$3,187.61
325000	9.62	615.96	85.71	2594.80	90.22	$3,396.31
350000	10.36	617.05	86.05	2794.40	97.16	$3,605.03
375000	11.10	618.15	86.40	2994.00	104.10	$3,813.75
400000	11.84	619.26	86.75	3193.60	111.04	$4,022.49

SCREW CONVEYOR WITH STEEL FLIGHTING

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	15.4
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	107500
Power Requirements (hp)	12.6
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$2,031.20
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.5
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	222.01	30.02	0.00	0.00	$252.02
25000	1.41	222.22	30.09	249.38	4.19	$507.28
50000	2.81	222.44	30.16	498.75	8.37	$762.53
75000	4.22	222.66	30.23	748.13	12.56	$1,017.79
100000	5.63	222.89	30.30	997.50	16.74	$1,273.05
125000	7.03	223.11	30.37	1246.88	20.93	$1,528.31
150000	8.44	223.33	30.44	1496.25	25.12	$1,783.57
175000	9.85	223.56	30.51	1745.63	29.30	$2,038.84
200000	11.25	223.78	30.58	1995.00	33.49	$2,294.10
225000	12.66	224.01	30.65	2244.38	37.67	$2,549.37
250000	14.07	224.24	30.72	2493.75	41.86	$2,804.63
275000	15.47	224.46	30.79	2743.13	46.05	$3,059.90
300000	16.88	224.69	30.87	2992.50	50.23	$3,315.17
325000	18.28	224.92	30.94	3241.88	54.42	$3,570.44
350000	19.69	225.16	31.01	3491.25	58.60	$3,825.71
375000	21.10	225.39	31.09	3740.63	62.79	$4,080.99
400000	22.50	225.62	31.16	3990.00	66.98	$4,336.26

SCREW CONVEYOR WITH BRISTLE FLIGHTING

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	15.4
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	58750
Power Requirements (hp)	16
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$3,561.70
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.3
Labour Rate ($/h)	$9.00

CALCULATION TABLE (BRISTLE)

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	389.29	52.64	0.00	0.00	$441.92
25000	3.27	389.99	52.86	149.78	7.66	$603.55
50000	6.54	390.70	53.08	299.55	15.32	$765.18
75000	9.80	391.41	53.31	449.33	22.98	$926.82
100000	13.07	392.13	53.53	599.10	30.64	$1,088.47
125000	16.34	392.86	53.76	748.88	38.30	$1,250.13
150000	19.61	393.59	53.99	898.65	45.96	$1,411.80
175000	22.88	394.33	54.23	1048.43	53.62	$1,573.47
200000	26.14	395.07	54.46	1198.20	61.28	$1,735.16
225000	29.41	395.82	54.70	1347.98	68.94	$1,896.85
250000	32.68	396.58	54.94	1497.75	76.60	$2,058.55
275000	35.95	397.35	55.18	1647.53	84.26	$2,220.26
300000	39.22	398.12	55.42	1797.30	91.91	$2,381.97
325000	42.49	398.89	55.67	1947.08	99.57	$2,543.70
350000	45.75	399.68	55.92	2096.85	107.23	$2,705.44
375000	49.02	400.47	56.17	2246.63	114.89	$2,867.18
400000	52.29	401.27	56.42	2396.40	122.55	$3,028.93

PADDLE CONVEYOR

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	15.4
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	128750
Power Requirements (hp)	10.7
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$4,600.00
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.1
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	502.77	67.98	0.00	0.00	$570.75
25000	1.00	503.18	68.11	49.98	3.50	$625.76
50000	1.99	503.60	68.24	99.95	6.99	$680.77
75000	2.99	504.01	68.37	149.93	10.49	$735.79
100000	3.99	504.43	68.50	199.90	13.98	$790.81
125000	4.99	504.85	68.64	249.88	17.48	$845.82
150000	5.98	505.27	68.77	299.85	20.97	$900.84
175000	6.98	505.69	68.90	349.83	24.47	$955.87
200000	7.98	506.12	69.04	399.80	27.96	$1,010.89
225000	8.98	506.54	69.17	449.78	31.46	$1,065.92
250000	9.97	506.97	69.31	499.75	34.95	$1,120.95
275000	10.97	507.40	69.44	549.73	38.45	$1,175.98
300000	11.97	507.83	69.58	599.70	41.94	$1,231.02
325000	12.96	508.26	69.71	649.68	45.44	$1,286.05
350000	13.96	508.70	69.85	699.65	48.93	$1,341.09
375000	14.96	509.13	69.99	749.63	52.43	$1,396.13
400000	15.96	509.57	70.13	799.60	55.92	$1,451.17

BELT CONVEYOR

INPUTS

CROP MATERIAL	LENTILS
MOISTURE CONTENT (%)	15.4
CONVEYOR SPEED (RPM)	540
CONVEYOR ANGLE (DEGREES)	30
Tractor Cost ($/hp-h)	$0.24
Conveyor Capacity (LB/h)	78130
Power Requirements (hp)	4.2
Conveyor Salvage Value (%)	5
Conveyor Purchase Price ($)	$5,513.00
Commodity Price ($/LB-%)	$1.00
Commodity Damage Rate (%)	0.1
Labour Rate ($/h)	$9.00

CALCULATION TABLE

ANNUAL PRDCT'N LB/yr	POWER COST $/yr	FIXED COST $/yr	REPAIR COST $/yr	GRAIN DAMAGE $/yr	LABOUR (STANDBY) $/yr	TOTAL COST $/yr
0	0.00	602.56	81.47	0.00	0.00	$684.03
25000	0.65	603.38	81.73	49.98	5.76	$741.49
50000	1.29	604.20	81.99	99.95	11.52	$798.95
75000	1.94	605.02	82.25	149.93	17.28	$856.41
100000	2.58	605.85	82.51	199.90	23.04	$913.89
125000	3.23	606.69	82.78	249.88	28.80	$971.37
150000	3.87	607.53	83.04	299.85	34.56	$1,028.86
175000	4.52	608.38	83.31	349.83	40.32	$1,086.35
200000	5.16	609.24	83.58	399.80	46.08	$1,143.85
225000	5.81	610.09	83.85	449.78	51.84	$1,201.36
250000	6.45	610.96	84.12	499.75	57.60	$1,258.88
275000	7.10	611.83	84.40	549.73	63.36	$1,316.40
300000	7.74	612.70	84.68	599.70	69.12	$1,373.94
325000	8.39	613.59	84.95	649.68	74.88	$1,431.48
350000	9.03	614.47	85.23	699.65	80.63	$1,489.02
375000	9.68	615.37	85.52	749.63	86.39	$1,546.58
400000	10.32	616.26	85.80	799.60	92.15	$1,604.14